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Greenhouse Vegetable Crops -- 1981: A Summary of Research

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CONTENTS

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ON THE COVER: Researchers are testing the use of white plastic mulch on several greenhouse tomato varieties. Increased light reflectivity from the mulch could increase tomato yields during the winter growing season.

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Influence of White Plastic Mulch on the Yield of Four Varieties of Spring Crop Tomatoes

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INTRODUCTION

A major problem with growing greenhouse tomatoes during the winter in Ohio is the lack of light due to low sunlight intensities and short day lengths. Use of white polyethylene mulch (wpm) might be advantageous, since more light would be reflected back to the plants rather than absorbed by the soil. The objective of this study was to see if a yield advantage would result from the use of wpm with several greenhouse tomato varieties.

MATERIALS AND METHODS

Four cultivars were used: Ohio M-R 13, the most widely grown greenhouse tomato cultivar in Ohio; Hybrid 7, an experimental F_1 which is being widely grown as a fall tomato in Ohio; ES5, an experimental inbred which has shown promise under low light conditions; and ES10, an experimental inbred with good fruit size but no TMV resistance. Seed was planted in flats of sand on Oct. 10, seedlings were pricked out into 4-inch pots on Oct. 22, and plants were transplanted to groundbeds on Dec. 12, 1979.

Two mulches were used: wpm[2] covering the 36-inch aisles between rows and peanut hulls. Plants were spaced 18 inches within rows which were 36 inches apart, equivalent to 9,680 plants per acre. A split-plot design was used with mulch as the main plot and cultivar as the subplot. There were three blocks within each mulch treatment with five plants per experimental unit.

One pint of 10-52-8 starter fertilizer (2 tbsp/gal) was applied at transplanting. During the season, 200 lb/A KNO_3 and 80 lb/A muriate of potash (0-0-62) were applied. The plants were pollinated every other day with an electric vibrator and harvested twice weekly at the breaker stage. The first harvest was made on Feb. 11 and the last on June 23. The crop was topped on May 6. Temperatures were generally 70-75° F during the day and 62° F at night. Watering was done via overhead irrigation lines.

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RESULTS AND DISCUSSION

The effect of mulch on yield is given in Table 1. The data indicate wpm increased total and #1 fruit weight per plant for the early harvest, but had no effect on total yield. By observation, total yields on wpm were not optimal due to heavy early fruit load which slowed later growth. Nevertheless, the early yield increase with wpm over peanut hulls is significant since the market price for early tomatoes is generally better than that for late season tomatoes.

All cultivars responded similarly to the mulch treatments. Therefore the average yields for all cultivars from the two mulch treatments are given in Table 2. ES10 had good early yield and superior overall fruit size with a low percentage of small fruit. Unfortunately the lack of TMV resistance limits the usefulness of this inbred. ES5 showed some promise with larger fruit size and total yield than M-R 13 but the grade was not as good. Fruit size for all cultivars increased later in the season with increasing light intensity.

More definitive conclusions could be made with further testing in other years, but these results suggest an advantage to using wpm during the spring crop. Changes in water and fertilizer applications may be necessary since fruit load may increase and evaporation from soil will be reduced.

TABLE 1.—Effects of Mulch on Average Yield of Four Cultivars of Greenhouse Tomatoes, Spring Crop, 1980, Columbus, Ohio.

	Early Harvest*			Total Harvest		
Mulch	Fruit Size (oz)	Fruit Wt/ Plant (lb)	#1 Fruit Wt/ Plant (lb)	Fruit Size (oz)	Fruit Wt/ Plant (lb)	#1 Fruit Wt/ Plant (lb)
(1) White Plastic	3.9 a†	1.00 a	0.85 a	5.4 a	13.70 a	9.73 a
(2) Peanut Hulls	3.8 a	0.36 b	0.31 b	5.2 a	13.20 a	9.69 a

*Early harvest=Fruit from first nine harvests, Feb. 7 to March 10.

†Means not followed by the same letter are significantly different by Duncan's multiple range test at the 5% level.

TABLE 2.—Comparison of Yields for Four Cultivars Grown in the Mulches Trial, Spring Crop, 1980, Columbus, Ohio.

	Early Harvest*				Total Harvest			
Variety	Fruit Size (oz)	Fruit Wt/ Plant (lb)	Percent #1 Fruit/ Plant	Percent Small† Fruit/Plant	Fruit Size (oz)	Fruit Wt/ Plant (lb)	Percent #1 Fruit/ Plant	Percent Small Fruit/Plant
ES 10	4.8 a‡	0.98 a	89.3 a	4.7 a	6.3 a	13.71 ab	70.4 a	4.1 b
ES 5	4.0 ab	0.55 b	65.0 b	19.8 a	5.5 b	14.54 a	61.3 b	8.8 a
Hyb. 7	3.8 ab	0.64 ab	65.6 b	10.9 a	4.7 c	14.06 a	71.9 a	8.3 a
M-R 13	2.8 b	0.55 b	68.4 ab	21.5 a	4.5 c	11.49 b	73.2 a	10.7 a

*Early Harvest=Fruit from first nine harvests, Feb. 7 to March 10.
†Small Fruit=Fruit less than 3 oz in weight.
‡Means not followed by the same letter are significantly different by Duncan's multiple range test at the 5% level.

Evaluation of Selected Insecticides for Insect Control on Greenhouse Vegetables

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INTRODUCTION

As part of an IR-4 Program[2] (National Committee for minor uses of pesticides), several insecticides were evaluated on greenhouse tomato, cucumber, and leaf lettuce. The insecticides selected were those judged to be among the top priority materials for use on greenhouse vegetables. This article is a summary of the current status of this work.

MATERIALS AND METHODS

The following insecticides were evaluated on one or more crops: resmethrin (SBP-1382), pirimicarb (Pirimor), permethrin (Ambush), oxamyl (Vydate L). Materials were applied with 1.5 gal (5.7 *l*) compressed-air sprayers at 40 psi (2.8 kg/cm^2), or a Hudson suburban power sprayer (10 gal capacity, (38 *l*) at 150 psi (10.5 kg/cm^2)). Sprays were generally applied to runoff, although in some cases this was limited to 100 gal/acre (950 *l*/ha). From 4 to 5 spray applications were made to each crop, usually at weekly intervals.

Each treatment was replicated four times, with 3 to 12 plants per replicate, depending on the crop being evaluated. In most experiments tomatoes and cucumber plants were grown in rows in soil bed greenhouse compartments. In one trial to evaluate several materials for leafminer control, tomato plants were grown in 4-inch (10 cm) diam. pots. Leaf lettuce was grown in 2 ft x 2 ft (60 cm x 60 cm) plots in Metro-Mix 200.

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[2]IR-4 provided partial funding for both efficacy and residue portions of this study. Imperial Chemical Industries and E. I. duPont de Nemours & Company also provided residue analyses.

Natural infestations of the greenhouse whitefly and vegetable leafminer were used, whereas green peach aphids and cabbage looper larvae were introduced onto plants prior to application.

Greenhouse Whitefly, *Trialeurodes vapororiorum* Westwood

Resmethrin sprays gave excellent control of whiteflies on greenhouse tomatoes, as measured by nymph counts in the first experiment (Table 1) and short-term adult control in a second (Table 2). Some phytotoxicity was seen in the first trial, but was minor at the 4 oz (120 ml) rate. No injury was seen in the second experiment at any of the application rates, even though the same number of applications was made to fruiting plants. Control in both experiments probably would have been better if all plants in the greenhouse had been treated. The residual effect of resmethrin is minimal, and whiteflies recolonized treated plants shortly after treatment.

Oxamyl sprays at 4, 8, and 16 oz ai/100 gal (applied to 1 acre or 0.4 ha) (120, 240, 480 ml/380 *l*) also gave some whitefly control on tomato (Table 3). There were no apparent differences among the three rates used and no phytotoxicity was observed. Fruit samples were taken for later residue analysis by the duPont Company.

Cabbage Looper, *Trichoplusia ni* (Hubner)

Second and third instar cabbage looper larvae were placed on leaf lettuce plants several hours before application, and the number of live larvae were recorded 24 hr later. All application rates of resmethrin gave excellent control (Table 4). No phytotoxicity was observed with any of the application rates.

TABLE 1.—Greenhouse Whitefly Control on Greenhouse Tomato After Foliar Spray Applications of Resmethrin.

Treatment*	Rate: oz ai/100 gal	Rate: ml ai/380 *l*	Mean No. Whitefly Nymphs†
Untreated			20.7 a
Resmethrin 2 EC‡	4	120	0.05 b
Resmethrin 2 EC**	8	240	0 b

*Applied March 10, 17, 24, 31, and April 6, 1978. Applications made to run-off with a Hudson power sprayer; cv. 'Ohio MR-13'.

†Means of four replications; nymphs recorded from two subapical leaflets/plant on four plants/replicate. Recorded 7 days following last application. Means followed by same letter are not significantly different at the .05 probability level according to Duncan's multiple range test.

‡Caused minor chlorosis-necrosis on upper half of a few plants. Damage not severe.

**Caused moderate chlorosis-necrosis on some younger foliage. Acceptability of injury questionable.

TABLE 2.—Greenhouse Whitefly Control on Greenhouse Tomato After Foliar Spray Applications of Resmethrin.

Treatment*	Rate		Mean No. Nymphs†					
	oz ai/100 gal	ml ai/380 *l*	6/11	6/12	6/18	6/21	7/2	7/3
Resmethrin 2 EC	2	60	51.6	4.1	40.1	11.2	86.3 b	7b
Resmethrin 2 EC	4	120	52.7	5.2	18.3	3.2	36.2 b	6.2 b
Resmethrin 2 EC	8	240	114.3	2.1	20.4	2.0	49.5 b	17.8 b
Untreated			44.8	53.2	71.8	69.2	104.8 a	292.9 a

*Applications made to run-off with a compressed-air sprayer on June 11, 18, 25; July 2, 9, 1979; cv. 'Ohio MR-13'.
†Means of four replications; adults recorded from two apical leaves on each of three plants/replicate; means in each column with a letter in common are not significantly different at the .05 probability level according to Duncan's multiple range test.

Green Peach Aphid, Myzus persicae **(Sulzer);**
Potato Aphid, Macrosiphum euphorbiae **(Thomas)**

Pirimicarb 50 WP was evaluated vs. *M. persicae* on leaf lettuce and *M. euphorbiae* on tomato. Applications were also made to cucumber, but no aphids were present. Residue analyses for pirimicarb and its toxic metabolites were made on all three crops.

All three application rates gave excellent control of *M. persicae* on lettuce when applied at weekly intervals (Table 5). On tomato, *M. euphorbiae* was apparently very susceptible to pirimicarb, because all aphids on untreated plants were killed, probably by pirimicarb volatilizing from treated plants.

Pirimicarb residues are shown in Table 6. Even after four or five applications, residues were low on tomato and cucumber, but quite high on leaf lettuce.

TABLE 3.—Greenhouse Whitefly Control on Greenhouse Tomato After Foliar Sprays of Oxamyl.

Rate*		Mean No. Nymphs†
oz ai/100 gal	ml ai/380 *l*	
4	120	2.9 b
8	240	2.6 b
16	480	3.7 b
Untreated		11.4 a

*Applications made with a compressed air sprayer on Oct. 17, 24, 31; Nov. 7, 14, 21, 28; Dec. 5, 12, 1978. All applications at 100 gal/acre (950 *l*/ha); cv. 'Ohio MR-13'.
†Means of four replications; nymphs recorded on four 2.5 cm diam. leaf discs/replicate; means followed by the same letter are not significantly different at the .05 probability level according to Duncan's multiple range test.

Vegetable Leafminer, Liriomyza sativae **Blanchard**

Resmethrin, permethrin, and oxamyl were evaluated at two application rates for leafminer control on tomato and compared with diazinon AG500. Three spray applications were made at weekly intervals, and completed leafmines recorded after each treatment. Permethrin, oxamyl, and diazinon all gave fair control under these conditions (Table 7). Leafminers were able to migrate freely from untreated plants during this trial, so control might have been better if the entire planting could have been treated with one material.

A second experiment involving application of permethrin to mature tomato plants in a soil bed compartment was conducted in cooperation with the Department of Horticulture. Unfortunately, no leafminers were present so efficacy data were not obtained. However, fruit was harvested for residue analysis.

The results of these experiments (both efficacy and residue) will be used to support label expansion for these insecticides, so that use on some greenhouse vegetable crops may be permitted.

TABLE 4.—Cabbage Looper Control on Greenhouse Leaf Lettuce After a Foliar Spray of Resmethrin.

Treatment*	Rate		Mean No. Live Larvae†
	oz ai/100 gal	ml ai/380 *l*	
Resmethrin 2 EC	2	60	0 a
Resmethrin 2 EC	4	120	0 a
Resmethrin 2 EC	8	240	0.15 a
Untreated			16.5 b

*Applied to run-off with a compressed air sprayer on Feb. 22, 1978.
†Means of four replications; larvae recorded from 12 plants/replicate 24 hr after treatment. Means followed by same letter are not significantly different at the .05 probability level according to Duncan's multiple range test.

TABLE 5.—Green Peach Aphid Control on Greenhouse Leaf Lettuce with Foliar Sprays of Pirimicarb.

Rate*		Mean No. Aphids per Leaf on Indicated Date†					
oz ai/100 gal	g ai/380 l	Feb. 5	Feb. 12	Feb. 15	Feb. 19	Feb. 23	Feb. 28
1	28	0	0	0.1	0	0	0
2	56	0	0	0.15	0	0	0
4	112	0	0	0.15	0	0	0
Untreated		1.15	2.85	6.15	9.2	11.4	23.1

*Applied to run-off with a compressed air sprayer on Feb. 2, 9, 19, 26, 1979.
†Means of four replications; aphids recorded from five leaves/replicate.

TABLE 6.—Residues of Pirimicarb and Its Toxic Metabolites on Greenhouse Vegetables After Foliar Spray Applications.

	Mean and Range of Pirimicarb Residues (ppm) on Indicated Days After Application*							
	0		1		3-4-5		7	
Plant	X†	2X†	X	2X	X	2X	X	2X
Tomato‡	0.24 (0.12–0.34)	0.28 (0.06–0.42)	0.01 (0.0045–0.02)	0.098 (0.015–0.16)	0.005 (0.0025–0.007)	0.03 (0.01–0.08)	0.06	0.009 (0 –0.02)
Cucumber**	0.09 (0 –0.28)	0.12 (0 –0.37)			0.06 (0 –0.14)	0.08 (0.02–0.14)	0.06 (0 –0.14)	0.05 (0 –0.12)
Lettuce††	9.9 (7.1 –12.6)	24.2 (13.8–30.1)	14.7 (10.0 –23.6)	20.3 (10.0 –25.9)	6.4 (5.6 –8.6)	8.4 (5.6 –10.8)	3.2 (1.4–4.5)	4.4 (2.8–5.2)

*Means of four replications; residues in untreated plants < 0.005.
†X=2 oz ai/100 gal (56 g/380 l).
‡Applied March 22, 29; April 5, 12, 19, 26; May 2, 9, 1979.
**Applied July 12, 19, 26; August 2, 1978.
††Applied Feb. 2, 9, 19, 26, 1979.

TABLE 7.—Control of the Vegetable Leafminer on Greenhouse Tomatoes with Foliar Sprays of Several Insecticides.

	Rate		Mean No. Leafminers/Plant on Indicated Dates†		
Treatment*	oz ai/100 gal	l ai/380 l	May 14	May 23	May 30
Resmethrin 2 EC	2	0.06	7.4 ab	1.25 b	16.1 a (0.38)‡
Resmethrin 2 EC	4	0.12	6.1 b	10.2 b	11.3 b (0.35)
Permethrin 2 EC	1	0.03	1.4 c	1.6 d	1.2 c (3.0)
Permethrin 2 EC	2	0.06	2.8 c	5.3 c	3.3 c (2.3)
Diazinon AG 500	4	0.12	2.5 c	2.8 cd	4.5 c (2.1)
Oxamyl 2 L	4	0.12	2.6 c	2.9 cd	3.7 c (2.5)
Oxamyl 2 L	8	0.24	2.3 c	2.6 cd	3.1 c (2.4)
Untreated			9.2 a	18.7 a	19.8 a (0.09)

*Applied on May 8, 16, and 23, 1979.
†Means of four replications, eight plants/replicate; completed leafmines recorded from each plant; means in each column with a letter in common are not significantly different at the .05 probability level, according to Duncan's multiple range test.
‡Number of dead larvae/plant.

Introduction of *Phytoseiulus persimilis* for Two-Spotted Spider Mite Control on Greenhouse Cucumber

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INTRODUCTION

In many European countries, the predatory mite *Phytoseiulus persimilis* is routinely (and successfully) used for controlling the two-spotted spider mite *(Tetranychus urticae)* on greenhouse cucumber and tomato crops (4, 9, 10). Predator introduction methods vary from the so-called "pest-in-first", or PIF, system (1) in which an even, low, infestation of the pest is established prior to introduction of predators only after pests are seen (natural infestation, or NI). A comparative study of each method in Finland (6) found that both methods were successful.

Several recent visits to Europe convinced me that *P. persimilis* should be utilized on U. S. greenhouse crops wherever possible. The major effort was directed at cucumber because spider mites often become severe problems, especially during warm weather months when greenhouse temperatures average 80° F (27° C) or more. Alternatives to conventional miticide applications on cucumber are desirable because of their general sensitivity to pesticides, resistant strains of spider mites, and lack of effective, registered pesticides. Experiments in small greenhouse compartments were successful, so preliminary experiments were organized with three commercial cucumber growers in southern Ohio. Results of these trials were mixed, and required applications of miticides to bring spider mite populations under control (unpublished data). The experiments described here were conducted since the preliminary trials, and were on a larger scale. Three commercial growers in northeast Ohio were cooperators, and a fourth experiment was conducted in an OARDC greenhouse.

MATERIALS AND METHODS

The first trial involved approximately 1200 plants, pollinated by bees, in NE Ohio. The grower wished to avoid having to remove the bees during spray applications, so invited us to try *P. persimilis* introductions. Spider mites were the only pests involved. The crop was planted out in late March, 1979, and a very low, isolated infestation of spider mites was noted on April 23. *P. persimilis* was released on these areas, and evenly throughout the greenhouse (total of 900 predators). A subsequent introduction of 100 predators was made on May 17.

The second and third experiments were conducted in the Cleveland area in greenhouses that produced both tomatoes and cucumbers. Cucumbers in these greenhouses were "European" or gynoecious (cv. 'La Reine'). The areas to be used in the experiments were partitioned off using polyethylene sheets. One experiment involved 6200 plants, and the other approximately 2000. In both cases, predator introductions began as soon as visible mite injury appeared (both locations on March 19, 1980). The larger planting received 1800 predators during the first months, while the smaller planting received 2000. *Encarsia formosa* also was released for whitefly control at both locations.

At the OARDC location, I noted that a spider mite infestation was apparent only on 1 to 2 plants (out of 80), so an experiment was organized to compare the PIF system with our current introduction scheme. The compartment was divided in half with polyethylene and the trial lasted from April to July, 1980. *P. persimilis* was introduced onto the infested area immediately (average of two predators/plant), with most predators concentrated near the infested sites. On the other (PIF) half of the compartment, spider mites were introduced onto each plant, followed by a predator introduction (2/plant) 7 days later. Leaf injury was rated according to the system outlined in a Glasshouse Crops Research Institute Bulletin (3). Also recorded were the presence or absence of spider mites and predators on each leaf, and fruit yields. Temperature and percent RH were recorded at two levels (approx. 4 ft above soil and just above tops of plants). Results of these experiments are summarized below.

RESULTS AND DISCUSSION

Spider mite control was completely successful only in the first commercial trial. In this case, spider mites appeared in low numbers on only a few plants, and the introduced *P. persimilis* kept them contained in isolated areas. In the other two commercial greenhouses, spider mites were found in large numbers also in relatively isolated areas, on March 10, 1980, probably from overwintering sites, on plants that already were approximately 7 ft tall. Our predator supply was not adequate to deal with the subsequent rapid spread of the spider mites from the originally-infested areas. A series of predator introductions, combined

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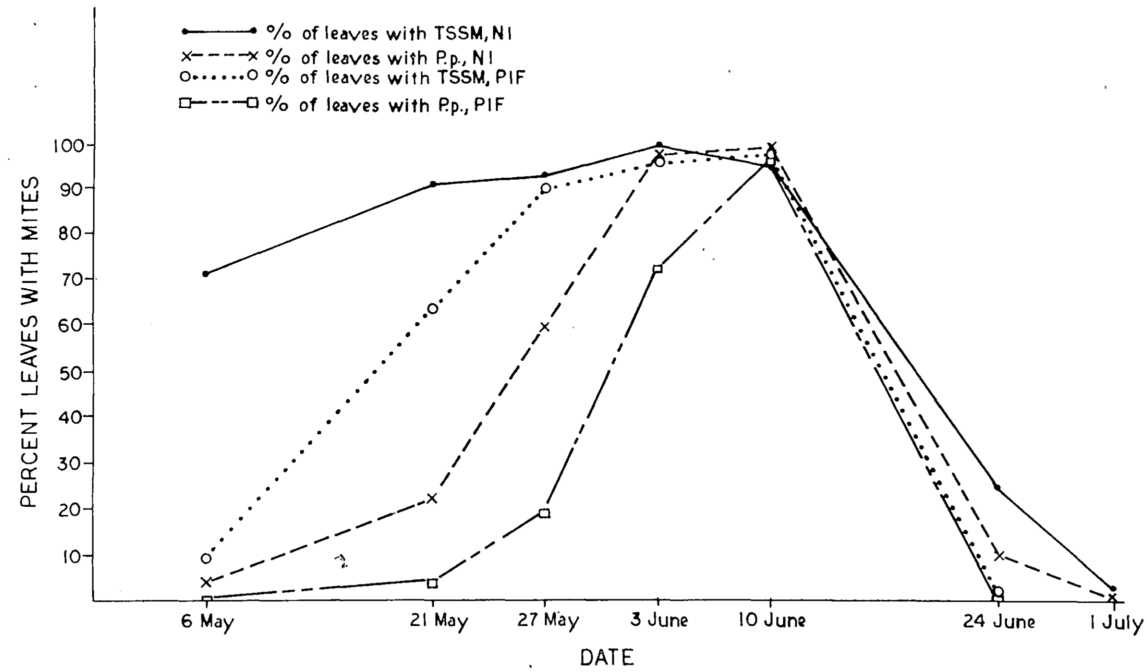

FIG. 1.—Percent of cucumber leaves containing T. urticae **and/or** P. persimilis. **NI = natural infestation; PIF = pest-in-first.**

with moving predators from different areas within the crop, eventually brought the spider mites under control, but not before severe crop injury appeared. The failure to achieve successful control in these trials probably was the result of too few predators for an already well-established prey population. Also, as reported by Hussey and Parr (5), predators do not disperse from prey-infested sites on cucumbers until active stages of the prey have been eliminated. Similar results were reported by Burnett (2) on greenhouse roses. Therefore, the prey probably spread more rapidly than predators in these trials. The last experiment in an OARDC greenhouse compartment was designed to compare PIF introductions with the scheme used in the other experiments (NI). Leaf injury ratings and percent of leaves with predator and

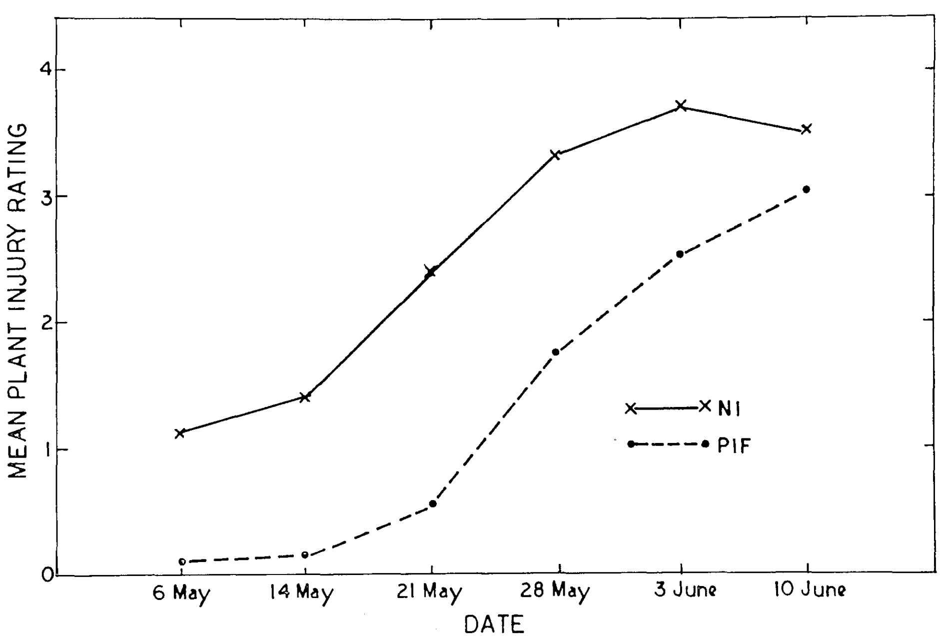

FIG. 2.—Plant injury rating with two predator introduction schemes. NI = natural infestation; PIF = pest-in-first.

prey are shown in Figures 1 and 2. The infestation levels at the beginning of the experiment (Fig. 1) were very different, but within 4 to 5 weeks were similar. Both spider mite populations were brought under control at about the same time. It is clear that predators were not able to contain spider mites in either case, but in the PIF introduction, yields were much higher (4.0 fruits/plant vs. 1.1 fruits/plant, harvested from May 22 to June 13). Apparently, predators were able to delay the onset of severe injury enough to allow fruit production. Leaf injury ratings were discontinued after June 10, because many severely injured leaves had dried and fallen from plants. Also, the most severe injury on the PIF plants was concentrated on upper leaves, whereas the NI plants had severe injury on most leaves. Temperatures and percent RH averaged 27.5° C (Range: 21-31.5), 77.2%; and 24.5° C (Range: 18.5-29.5), 85.1%, for the locations above and within the crop, respectively. These conditions are reported to be very favorable for *P. persimilis,* according to Pralavorio and Almaquel-Rojas (7) and Pruszynski (8). The PIF system seemed to give better overall results in this case, but more work is needed on predator introduction onto Ohio greenhouse cucumber crops. Perhaps the reasons for the failure of *P. persimilis* to rapidly control the spider mite population on the PIF treatment were same as for the NI experiments described earlier, *i.e.,* too few predators, and the spider mites dispersed more rapidly than the predators. It may be necessary to introduce predators earlier in the crop (fewer leaves to search) and at a higher predator:plant ratio than used here. The economics of introducing large numbers of predators may be a significant factor, if growers purchase them from a private supplier.

ACKNOWLEDGMENT

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Introduction of *Encarsia formosa* for Greenhouse Whitefly Control on Greenhouse Tomatoes: A Summary of Progress

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INTRODUCTION

Two recent articles by Lindquist *et al* (3, 4) outlined biological and integrated control efforts on vegetable and selected ornamental plants in Ohio with the whitefly parasite *Encarsia formosa* Gahan and the two-spotted spider mite predator *Phytoseiulus persimilis* (Athias-Henriot). This paper summarizes additional commercial and experimental trials on greenhouse vegetables, using *E. formosa* to control the greenhouse whitefly, *Trialeurodes vaporariorum.*

MATERIALS AND METHODS

Several experiments on tomato crops were conducted to gain experience with *E. formosa* rearing and introduction techniques developed in England and The Netherlands. Generally, parasites were introduced at a total of 5/plant, in a series of 3 to 4 releases beginning shortly after the first whitefly adults were seen. Introductions were made approximately fortnightly.

Commercial trials were done in the Cleveland, Ohio, area with growers having small (less than ¼ acre) isolated, greenhouse compartments. Crops were transplanted into ground beds early in January. Each cooperator was instructed to telephone as soon as the first adult whiteflies were observed. Other experiments were conducted in OARDC Entomology and Plant Pathology greenhouses where observations could be made on a more regular schedule. In one OARDC experiment, plants were transplanted into the ground bed on February 14, and whitefly adults observed on March 6. *E. formosa* was introduced twice, on March 14 and 30, each at 2 parasites/plant.

The success of *E. formosa* in controlling two initial levels of whitefly populations was evaluated in two OARDC greenhouse compartments. In one (Entomology) greenhouse, 80 tomato plants contained an average of nine adult whiteflies/apical leaflet. The other (Plant Pathology) greenhouse contained 600 plants, averaging two adults/apical leaflet. Controls in both houses set at 62° F night temperatures, with ventilators opening at 75° F. Both houses were planted early in January, and whiteflies were observed shortly after plants had been placed in soil beds. *E. formosa* was introduced into each greenhouse, beginning January 23 (2/plant). Subsequent introductions were made as follows: Entomology, February 5 (2/plant) and February 20 (1/plant); Plant Pathology, February 5 (2/plant) and March 8 (1/plant). The number of adult whiteflies was counted at weekly intervals on apical leaves and yellow cards (5 x 8-in) with both sides coated with Tack-Trap. Cards were hung from overhead wires.

The spread of *E. formosa* parasites from essentially one small location in an OARDC Plant Pathology greenhouse was measured as a supplement to a pesticide residue trial involving resmethrin. The greenhouse contained 45 rows of tomato breeding lines (approx. 700 plants), and all but four rows in one corner were being sprayed at 7-day intervals with different rates of resmethrin. When making efficacy evaluations, we noticed a "natural" population of *E. formosa* on untreated plants and decided to follow their spread to other areas of the greenhouse.

RESULTS AND DISCUSSION

At the outset of the commercial greenhouse experiments we realized that our (and the growers') interpretations of what constituted the first whiteflies were different. By the time we received word that whiteflies were present and arrived on the scene, the infestations were too heavy, especially for the low light period of winter, when *E. formosa* are not as effective. After a short time the experiments were abandoned. A subsequent trial was conducted with another cooperator, who telephoned when very few whiteflies were present. A series of *E. formosa* introductions was made as described earlier, only to observe after several weeks that whitefly populations were increasing rapidly, and very few parasitized whiteflies were observed. The problem in this case may have been poor *E. formosa* emergence. Apparently, storage of some parasites was at too low a temperature (42-44° F) for 7 to 10 days. Also, low greenhouse temperatures (68° F day, 62° night) and insecticide drift from an adjacent greenhouse may have been involved.

Results of a trial on approximately 45 tomato plants in an OARDC greenhouse are shown in Figure 1. Except for a brief population surge near the end of the crop, *E. formosa* kept whitefly populations under control. A localized infestation of the two-spotted spider mite *(Tetranychus urticae* Koch) was observed on May 15. The predator mite *Phytoseiulus*

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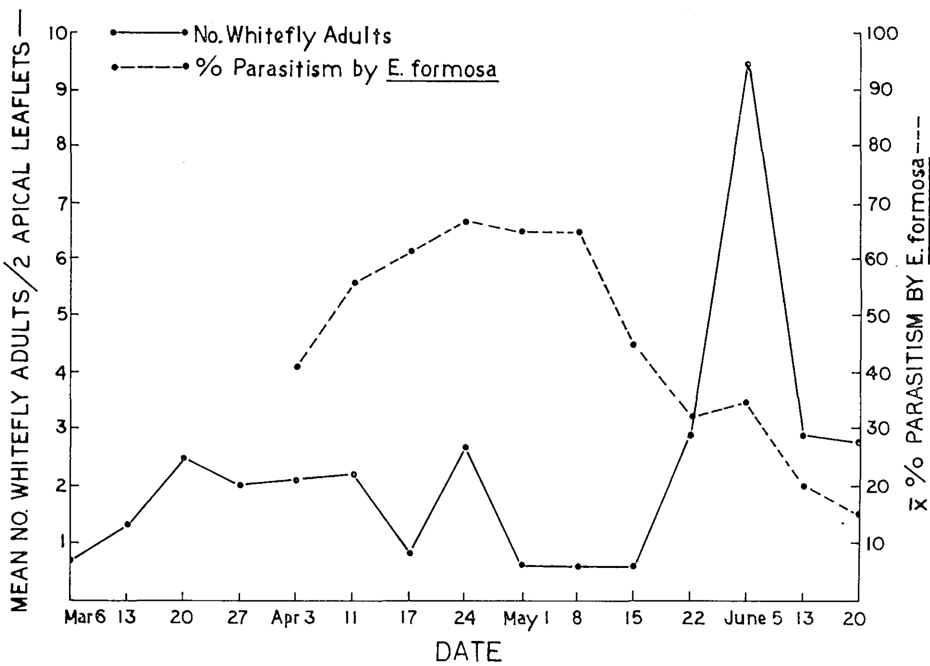

FIG.1.—Whitefly adult populations on greenhouse tomatoes and percent parasitism by E. formosa **after introduction of the parasite at 2/plant on March 14 and 30.**

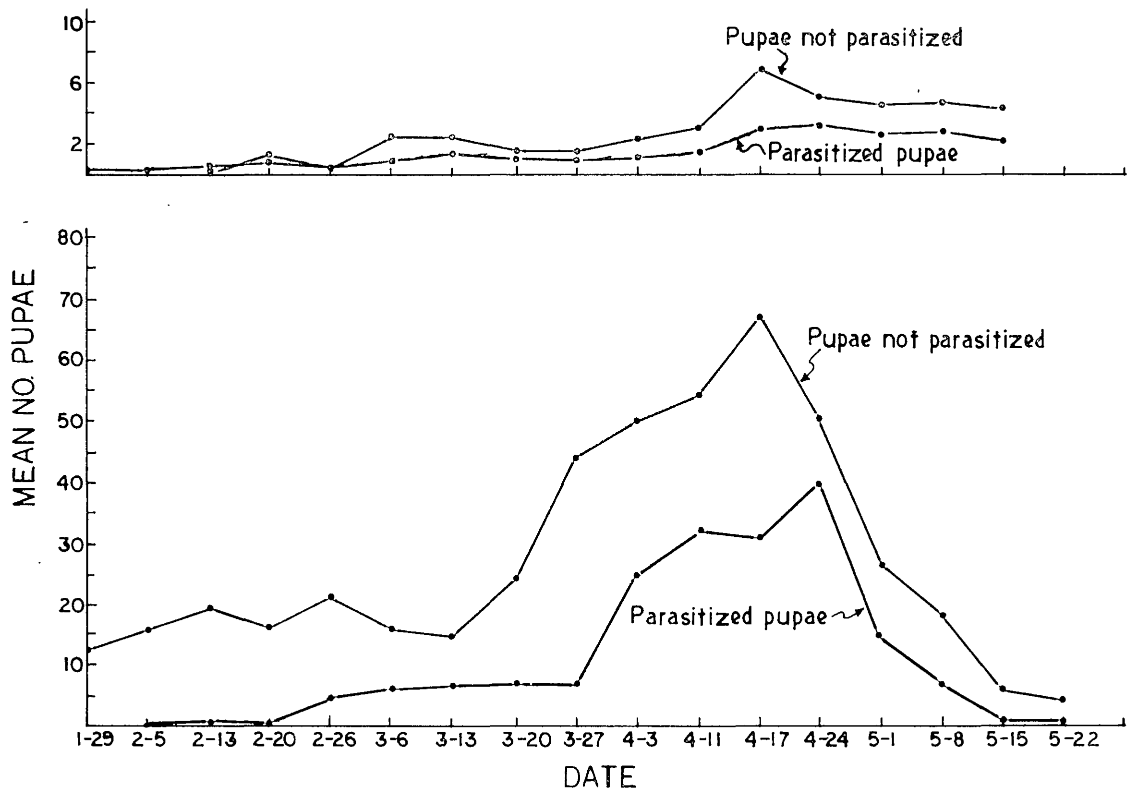

FIG. 2.—Parasitized and non-parasitized whiteflies after introducing the same number of E. formosa **into greenhouse tomatoes at 2 population densities. Upper graph = Plant Pathology; lower graph = Entomology.**

persimilis was released at the rate of 2/plant on two occasions (May 15 and 23) to control this pest. No other insect or mite pests invaded the greenhouse for the duration of the crop. Controls were set at 62° F night temperature, with ventilators opening at 78° F.

Results of the experiment measuring the effect of initial whitefly population density on control by *E. formosa* (Table 1) are weekly average totals/card. Parasitized and non-parasitized whitefly "pupae" were also observed in both greenhouses (Figure 2). In the Entomology greenhouse, observations were made on one terminal subapical leaflet on each of 20 plants (=25% of plants). Parasitism was measured on two plants in each of 28 rows in Plant Pathology (10% of plants).

Adult totals on yellow cards and parasitism both show what a difference the initial whitefly population on a crop can make. Sooty fungus appeared on plants in the Entomology greenhouse early in April. No sooty fungus was seen in the other crop. These results generally agree with those of Foster and Kelly (1), although our whitefly adult populations exceeded their minimum necessary for successful biological control in both cases. Possibly greenhouse temperatures in our trials were higher and relative humidity was lower, encouraging *E. formosa* and discouraging sooty fungus. Also, our plants were watered from above, which may have washed most of the honeydew off leaves. Foster and Kelly used growers' opinions concerning whether or not to spray as the criterion for success or failure of control. We had no such constraints, as our trial was not in a commercial greenhouse.

In observing the spread of *E. formosa* (Figure 3), the last spray application was on April 21, and dates when parasitized (black) whitefly nymphs were first observed in other areas are shown. Obviously, this experiment also measured the survival and spread of whiteflies. Within 4 weeks after the last application, black scales were found in all areas. The black scales observed on April 27 (7 days after sprays were stopped) had been parasitized before the last spray application, indicating that some whitefly and parasite survival is possible where resmethrin is being used. This is in agreement with Harbaugh (2). The number of adult whiteflies rose to nearly 20/apical leaflet briefly near the end of May (Table 2), but then declined. No sooty fungus formation was observed.

TABLE 1.—Adult Whiteflies Caught on Yellow Sticky Traps in Two Greenhouse Tomato Crops with Initial Differences in Whitefly Densities and the Same E. formosa **Introduction Rate.**

	Mean No. Whiteflies per Trap	
Date	**Entomology***	**Plant Pathology†**
Feb. 1	42	6
8	32	3
15	43	9
22	53	7
March 1	128	—
8	151	7
15	407	17
22	287	25
29	351	80
April 5	2827	166
12	1833	82
19	3827	133
26	4400	163
May 3	4000	308
10	1633	257
17	933	118

*One trap/20 plants.
†One trap/93 plants.

TABLE 2.—Number of Adult Whiteflies and Percent Parasitism After a Natural Spread From One Area.

Date	Adult Whiteflies/Two Apical Leaflets*	Percent Parasitism†
April 27	0.74	
May 4	0.42	
11	1.33	
18	16.97‡	
25	38.67	71.74
June 8	5.64	74.17
15	2.30	74.17

*Means of three plants from each of 23 rows.
†Parasitized and non-parasitized nymphs recorded from two subapical leaflets on three plants from each of 23 rows.
‡Parasitized whiteflies noted over entire greenhouse compartment.

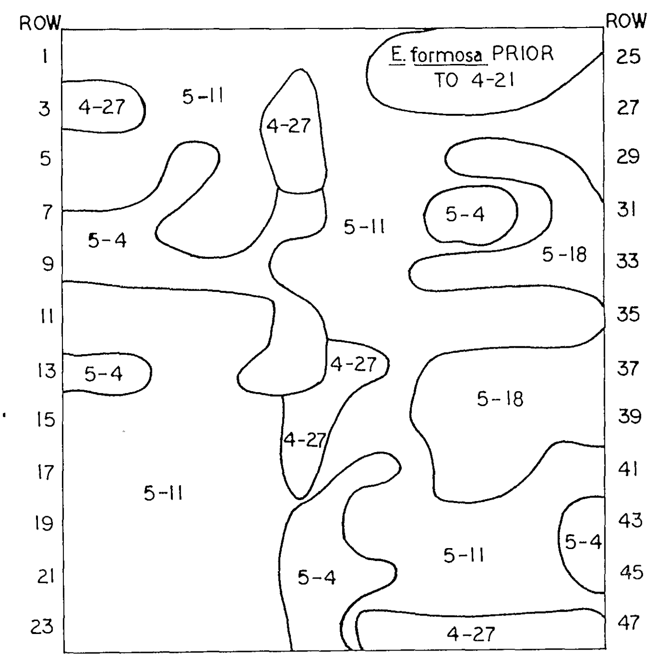

FIG. 3.—Date when E. formosa **was first observed in different areas of a greenhouse tomato crop.**

We conclude that resmethrin sprays could be used to treat isolated heavy whitefly infestations in a greenhouse, while allowing *E. formosa* to survive on adjacent, untreated plants.

Infestations of the vegetable leafminer *(Liriomyza sativae* Blanchard) occurred in both greenhouses, but appeared too late to warrant chemical control measures.

The results of these experiments illustrate the possibilities and problems with using *E. formosa* for controlling the greenhouse whitefly. In commercial trials, we found that the growers' interest in the project was one of the primary factors in its success or failure. A continuous educational effort will be necessary if widespread commercial use of bioloical and integrated control on greenhouse crops is to become a reality.

ACKNOWLEDGMENT

We thank the U. S. Environmental Protection Agency, Office of Pesticide Programs, for providing the majority of the funding for these experiments.

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Control of Botrytis Stem Canker in Greenhouse Tomatoes

RANDALL C. ROWE and JAMES D. FARLEY[1]

INTRODUCTION

Growers have traditionally controlled Botrytis stem canker by heating and venting to lower relative humidity and by occasional applications of fungicides such as Benlate or Botran. With increasing fuel costs, growers are heating and venting less and reducing air infiltration by sealing glass laps and by plastic coverings. These practices increase relative humidity and have resulted in increased Botrytis problems. Benlate application is not recommended due to the development of resistant Botrytis strains and Botran may cause plant injury and reduced yield.

Greenhouse growers in Europe are successfully using the fungicide Rovral for Botrytis control. This product, called RP-26019 in the United States, was tested in the plant pathology research vegetable greenhouse at the OARDC. Rhone-Paulenc Inc., Monmouth Junction, New Jersey, who produces RP-26019, partially supported this test.

MATERIALS AND METHODS

Eight-week-old tomato plants were transplanted into a steam-disinfected, silt-loam soil ground bed in a glass greenhouse on December 18, 1979. Plants were spaced 12 inches apart in 10 rows 3 feet apart and supported on a string trellis system. A randomized block design was used with five plants per treatment replicated four times. Just prior to the first spray application, autoclaved oats colonized with *Botrytis cinerea* were scattered between the rows to provide an inoculum source. Spray treatments were begun on January 7 and continued at 2-week intervals until May 15 for a total of 10 applications. Prior to each spray, the oat inoculum was covered with plastic film to prevent spray contamination. Sprays were applied to run-off with a hand-pump, backpack pressure sprayer. Lannate 1.8L or Dibrome 8ES were applied at 2 to 3 week intervals throughout the test for whitefly control. Temperatures throughout the experiment varied from 60-80° F. Infection data were taken on May 29 by examining the basal stem of each plant for Botrytis stem rot lesions.

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RESULTS AND DISCUSSION

Disease development was low throughout the test and one replication was discarded because no disease symptoms were evident even on unsprayed plants. In spite of this, control of *Botrytis* with RP-26019 was observed, especially at the ¾ and 1 lb rates. No phytotoxicity was observed. Benlate, included as a standard, was less effective. In recent years Benlate has become ineffective in most commercial greenhouse ranges because of resistant strains of the fungus. This test and one with similar results last year indicate that RP-26019 may be useful in *Botrytis* control where Benlate is no longer effective.

TABLE 1.—Effects of Fungicide Treatments for Control of Botrytis.

Treatment	Rate lb ai/100 gal water	Average Disease Rating/Plant*	Average Percent Plants Infected
RP-26019 50WP	½	0.3	33
RP-26019 50WP	¾	0.1	13
RP-26019 50WP	1	0.1	7
Benlate 50WP	¼	0.7	53
Untreated Control		1.1	67

*Stem lesions evaluated as 0=none visible, 1=single small lesion < 0.5 cm diam, 2=medium lesion 0.5-1.5 cm diam. or more than one small lesion, 3=large lesion > 1.5 cm diam, or more than one medium lesion,or 4=plant dead due to stem girdling.

Evaluation of Fusarium Crown and Root Rot Resistant Greenhouse Tomatoes

J. W. SCOTT and JAMES D. FARLEY[1]

INTRODUCTION

Fusarium crown and root rot (FCRR) has been one of the most serious greenhouse tomato diseases in Ohio and Ontario, Canada, since 1975 (1). Breeding for commercial level resistance to this disease has been one of the primary goals of our breeding program for the past five years. Resistance is governed by a single dominant gene which makes the breeding of F_1 hybrids feasible since this and many other resistances (Fusarium races I and II, Verticillium, root-knot nematode) have to be fixed in only one of the two parents of a hybrid variety.

The source of FCRR resistance, a Japanese line, was backcrossed two or three times to Ohio greenhouse inbreds and selfed to the F_5 generation. In 1978 we made our first FCRR resistant hybrids between the FCRR inbreds and some of our better non-FCRR greenhouse inbreds. These hybrids were grown for the first time in spring 1980 trials in Columbus, Wooster, Harrow Canada, and several commercial ranges in Cleveland, Ohio, and Leamington, Ontario. This report presents data as to the performance of these new hybrids in the Columbus trial.

MATERIALS AND METHODS

Seeds were sown on Nov. 13, 1979, seedlings were pricked out into 4-inch pots on November 23 and transplanted into groundbeds on Jan. 8, 1980. Plants were spaced 18 inches apart within rows 36 inches apart, equivalent to 9,680 plants per acre. Each cultivar was planted in a 10 plant plot. A starter solution of 10-52-8 (2 tbsp/gal) was applied during ground bed setting at the rate of one pint per plant. One hundred lb/A potassium nitrate and 80 lb/A muriate of potash (0-0-62) were applied during the growing season. The plants were pollinated with an electric vibrator every other day. Harvesting began on Mar. 10 and ended on June 23. The crop was topped on May 6. Temperatures were generally 70-75° F during the day and 62° F at night. Watering was done with overhead irrigation.

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RESULTS AND DISCUSSION

Yield data are given in Table 1. The inbred 89-1 appears the most promising of the three FCRR inbreds, 1-1, 23-1, and 89-1. Its fruit size and yield were superior to the other two lines. Of the non-FCRR parents, ES2, 1239A, and NV8, 1239A was superior, with all three being comparable or better than Ohio M-R 13 for size and yield.

All hybrids are resistant to FCRR, Fusarium wilt race I, Verticillium wilt, and tobacco mosaic virus. In addition, hybrids CR #7, CR #8, and CR #9 are resistant to root knot nematodes, a trait acquired from the NV8 parent.

The fruits from hybrids of 1-1 parentage (CR #1, CR #4, and CR #7) are too small as indicated by fruit size and percent small fruit. Hybrids of 23-1 parentage (CR #2, CR #5, and CR #8) are good from a size and yield standpoint but the vines tend to be too vigorous for a spring tomato when grown in soil. Also, after crosses were made, 23-1 was found to be blotchy ripening susceptible, and therefore is not a suitable parent. Thus, only hybrids with 89-1 parentage (CR #3, CR #6, and CR #9) appear to have potential. Although their yields are not superior to 89-1, the hybrids are less vigorous which is an advantage. It appears the hybrids are as good as M-R 13 without as much zippering. Some seed of CR #6 has been ordered for commercial testing in Leamington, Ontaria for next year. In Ohio commercial ranges the hybrids appeared too vigorous.

These hybrids appear to be a reasonable start but perhaps not the definitive solution to FCRR problems. A new group of 36 FCRR hybrids, some with Fusarium race II resistance, are presently being tested. It is hoped that a commercially acceptable variey will result from this work in the near future.

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TABLE 1.—Evaluation of Fusarium Crown and Root Rot Resistant Hybrids and Inbreds, Spring 1980, Columbus, Ohio.

		Early Harvest*				Total Harvest					
	Genotypes	Fruit Size (oz)	Percent #1 Fruit	Percent Small Fruit†	Fruit Wt/Plant (lb)	Fruit Size (oz)	Percent #1 Fruit	Percent Small Fruit	Fruit Wt/Plant (lb)	Percent Zippers	Plant Vigor‡
1)	1-1	3.5	79	19	1.29	3.2	67	23	9.3	0.2	3
2)	23-1	4.4	86	14	1.66	3.0	64	31	11.09	0.4	5+
3)	89-1	6.7	97	0	1.60	5.6	80	6	13.57	0.5	5
4)	ES2	5.3	90	8	2.60	5.3	66	8	10.76	1.2	2
5)	1239A	5.7	91	9	1.94	5.2	65	10	14.80	0.3	3
6)	NV8	4.3	85	15	1.95	5.0	81	8	10.53	6.9	3
4 x 1)	CR #1	4.5	8.9	9	2.05	3.9	67	16	10.54	1.0	3
4 x 2)	CR #2	6.3	97	0	2.95	5.2	75	6	15.66	1.3	5
4 x 3)	CR #3	5.0	97	3	1.89	4.9	73	7	12.08	0.8	3
5 x 1)	CR #4	5.4	93	5	1.84	4.0	69	18	11.18	0.2	4
5 x 2)	CR #5	6.6	100	0	2.43	5.1	78	7	14.43	0.6	5
5 x 3)	CR #6	5.9	96	4	2.09	4.6	78	9	12.49	1.0	4
6 x 1)	CR #7	3.9	85	14	1.98	4.6	78	13	12.88	0.2	3
6 x 2)	CR #8	4.8	93	5	2.27	4.3	77	10	13.50	0.0	5
6 x 3)	CR #9	5.0	100	0	1.95	4.8	86	5	11.00	1.4	3
	Hybrid 7	5.1	97	3	2.38	4.5	60	14	10.38	2.4	4
	Hybrid 47	6.2	100	0	3.32	5.1	62	10	11.85	1.1	5
	M-R 13	4.5	84	3	2.20	4.8	71	10	10.13	10.9	2

*Early Harvest—First nine harvests March 10 to April 10.
†Small fruit are less than 3 oz in weight.
‡Subjective ratings rank from 1 to 5 where 1 = low vigor, 5 = high vigor.

Greenhouse Tomato Cultivar Evaluation Trial — Fall Crop, Columbus, 1979

J. W. SCOTT[1]

INTRODUCTION

The purpose of this yield trial was to evaluate several new Ohio experimental inbreds in relation to many of the standard greenhouse cultivars that are grown commercially or being developed elsewhere.

MATERIALS AND METHODS

Seed was planted in flats of sand on June 1, pricked out into 4-inch pots containing 2 soil:1 peat:1 vermiculite on June 12, and transplanted into ground beds on July 12. Plants were spaced 18 inches within rows which were 36 inches apart, equivalent to 9,680 plants per acre. A randomized block design was used with 40 cultivars, 2 blocks, and 5 plants of each cultivar per block. One pint 10-52-8 N:P:K starter fertilizer (2 tbsp/gal) was applied at transplanting and no other fertilizer was applied. A peanut hull mulch was used. Pollination was done every other day with an electric vibrator. The first harvest was made on Aug. 29 and the last on Nov. 26. The crop was topped on Oct. 3.

RESULTS AND DISCUSSION

Cultivar, disease resistance, fruit color, yield, and fruit defect data are given in Table 1. The crop suffered water stress for a period which resulted in some blossom end rot (BER) and probably an increase in smaller fruit.

Generally, cultivars without tobacco mosaic virus (TMV) resistance have larger fruit size and yield. For instance, 'Jumbo' was probably the best overall line but it lacks TMV resistance. Many other lines with superior fruit size and fewer small fruit also lack TMV resistance such as ES9, ES10, and GS244. TMV resistant inbreds which show some promise are ES2, ES4, 3226, 3232, 3233, and 3236. Most of these had more rough (#2) fruit, small fruit, and/or zippering than desired. However, grades of commercially grown cultivars such as Ohio W-R25, Ohio M-R13, and Ohio Hybrid 7 were somewhat low as well.

Zippering, epidermal scars caused by adnate anthers, has been a problem in Ohio M-R13 and is a problem with some of the breeding lines. Of note here are the nematode resistant inbreds (designated NV-) which generally zippered excessively. Generally none of the nematode resistant inbreds appeared outstanding. Hybrids using these inbreds should have better yields than these inbreds plus nematode resistance.

Some lines appeared more susceptible to blossom end rot than other lines. These include most of the Fusarium Crown Rot resistant (designated CR-) lines. Of the crown rot inbreds, CR16 and CR10 look encouraging. The best crown rot inbreds we have at present were not in this trial but CR16 and CR10 should be considered for future evaluation and development.

Several of the inbreds such as ES2, ES4, ESC1, and ESR1 have already been used as hybrid parent lines for crown rot and nematode resistant hybrids. Other inbreds (3226, 3232, 3233, 3236) may make good parents and deserve further testing. Once reasonably good inbreds are developed for each disease, *i.e.,* crown rot, nematodes, and fusarium race II (no experimental inbreds in this trial), we will have a better yardstick with which to measure future inbreds. For instance, once a good yielding crown rot inbred is developed, further improvements on defects such as zippering can be refined.

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TABLE 1.—Disease Resistance, Fruit Color, Yield, and Fruit Defect Data for Tomato Cultivars Grown for the Fall Crop in Columbus, 1979. Cultivars Arranged in Descending Order of Total Fruit Weight/Plant.

			Early Harvest				Total Harvest					
Cultivar*	Disease Resistance†	Fruit Color‡	Fruit Size (oz)	Fruit Wt /Plant (lb)	Percent #1 Fruit	Percent Small Fruit**	Fruit Size (oz)	Fruit Wt /Plant (lb)	Percent #1 Fruit	Percent Small Fruit**	Percent Zippers	Percent Blossom End Rot
ES2	V,F,T	P	5.0	1.37	71	7	5.2	9.62	51	36	3.8	4.5
ES10	V,F	P	6.7	2.09	72	4	6.0	9.55	70	14	4.7	3.8
ES4	V,F,T	P	5.0	2.38	57	3	5.4	9.41	54	20	5.1	6.0
Mo Hyb 805[A]	F,C	R	5.0	2.39	57	18	5.1	9.38	48	34	0.8	2.0
3233	F,T	P	6.2	1.64	50	13	5.5	9.17	45	21	8.2	1.7
3231	F,T	P	6.1	2.33	33	13	5.1	9.16	42	27	12.0	0.1
3226	V,F,T	P	5.4	1.58	48	15	5.3	9.03	55	22	1.7	0.5
Mo Hyb 756[A]	F,C	R	5.2	1.71	76	4	5.0	8.99	65	21	1.5	2.6
Mo Hyb 785[A]	F	R	4.7	2.18	47	16	4.9	8.98	50	33	1.8	5.8
3232	F,T	P	5.6	1.69	37	14	5.5	8.92	53	25	9.5	1.4
Jumbo[B]	F,FII,V	R	6.0	1.79	79	1	6.3	8.86	80	4	0.8	1.7
ESC1	V,F,T	P	5.4	1.42	48	12	5.1	8.85	60	22	0.0	0.0
CR16	V,F,T,CR	P	4.8	1.21	37	13	5.0	8.69	61	18	0.0	11.1
WR25	F	P	4.6	1.45	31	4	4.8	8.60	51	19	0.7	15.6
ES9	F	P	6.5	2.16	65	7	5.9	8.50	72	13	1.2	3.2
NV 13-2	V,F,N,T	P	4.6	1.94	52	22	4.6	8.47	50	36	14.6	1.4
3238	F,T	P	5.5	1.74	52	9	5.6	8.42	46	22	2.7	0.0
CR10	F,V?,T,CR	P	5.3	1.61	52	8	5.0	8.40	52	28	22.7	7.8
3236	F,T	P	6.4	1.89	72	0	6.1	8.30	57	11	9.5	0.0
3237	V,F,T	P	5.7	2.00	51	18	5.3	8.19	54	21	21.5	0.0
GS244[D]	F,T††	R	6.0	1.93	77	0	5.9	8.14	70	10	1.5	6.5
Ont Hyb 773[C]	F,T,C	P	4.8	2.67	54	13	4.7	8.02	45	36	0.5	1.7
NV 8-1	V,F,N,T	P	4.6	1.62	80	10	4.5	7.98	54	35	28.8	2.6
Hybrid 7	V,F,T	P	5.1	1.73	53	9	4.4	7.94	49	34	8.4	2.7
3225	F,T	P	5.0	1.51	34	11	4.8	7.71	40	32	7.5	2.6
ESR1	V,F,T	R	5.7	1.32	35	13	5.1	7.60	57	25	5.0	1.1
CR15	V,F,T,CR	P	4.9	1.27	59	13	4.7	7.48	58	25	0.9	8.4
ES1	F,V,T	P	5.1	1.83	58	14	4.9	7.44	47	32	4.3	4.3
Ohio M-R13	F,T	P	4.4	1.54	35	14	4.7	7.41	56	24	11.6	0.8
CR13	F,V?,T,CR	P	3.9	1.15	31	40	4.2	7.40	37	45	0.0	8.5
Ont Hyb 774[C]	F,T,C	P	4.7	2.30	63	18	4.5	7.39	55	32	1.1	4.3
NV7	V,F,N,T	P	5.0	0.78	79	4	4.9	7.15	60	32	21.5	1.2
3228	F,T	P	4.4	1.24	29	34	5.5	7.08	38	47	6.0	4.3
NV 8-2	V,F,N,T	P	4.1	1.00	69	25	4.6	6.94	42	41	29.6	0.0
CR12	F,V?T,CR	P	4.1	0.72	64	27	4.2	6.69	45	48	3.0	3.2
CR14	F,V?,T,CR	P	3.8	1.37	14	47	3.8	6.68	18	59	0.0	12.5
NV11	V,F,N,T	P	5.4	0.68	39	11	5.3	6.58	65	15	2.3	4.6
CR11	F,V?,T,CR	P	4.2	0.88	57	13	4.2	6.06	51	37	3.4	3.1
3229	V,F,T	P	4.3	0.94	73	16	4.7	5.90	52	35	5.3	1.5
$LSD_{.05}$			1.1	0.80	17	15	0.9	1.59	14	14	3.1	5.8

*All cultivars are from the Ohio breeding program unless marked as follows:
[A]=Dept. of Hort., Univ. of Missouri, Columbia, Mo. 65201 (Dr. Vic Lambeth).
[B]=Bruinsma Seed Co., PO Box 24, Naaldwijk, The Netherlands.
[C]=Hort. Exp. Sta., Box 246, Simcoe, Ontario, Canada N3Y4L1 (Dr. Ernie Kerr).
[D]=Goldsmith Seeds, Inc., Route 1, Box 2145, Davis, Calif. 95616.
‡Fruit Color Codes: P=Pink, R=Red.
**Small fruit are less than 3 oz.
††Heterozygous (Tm2[a]) resistance, not considered adequate in Ohio due to possible necrosis.

†Disease Codes:
V=Verticillium Wilt Resistance.
F=Fusarium Wilt Resistance (race I).
FII=Fusarium Wilt Resistance (race II).
N=Root Knot Nematode Resistance.
T=Tobacco Mosaic Virus Resistance (TMV).
CR=Fusarium Crown Rot Resistance.
C=Cladosporium Leaf Mold Resistance.

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Research is conducted by 15 departments on more than 7000 acres at Center headquarters in Wooster, eight branches, Pomerene Forest Laboratory, North Appalachian Experimental Watershed, and The Ohio State University.

Center Headquarters, Wooster, Wayne County: 1953 acres

Eastern Ohio Resource Development Center, Caldwell, Noble County: 2053 acres

Jackson Branch, Jackson, Jackson County: 502 acres

Mahoning County Farm, Canfield: 275 acres

Muck Crops Branch, Willard, Huron County: 15 acres

North Appalachian Experimental Watershed, Coshocton, Coshocton County: 1047 acres (Cooperative with Science and Education Administration/Agricultural Research, U. S. Dept. of Agriculture)

Northwestern Branch, Hoytville, Wood County: 247 acres

Pomerene Forest Laboratory, Coshocton County: 227 acres

Southern Branch, Ripley, Brown County: 275 acres

Vegetable Crops Branch, Fremont, Sandusky County: 105 acres

Western Branch, South Charleston, Clark County: 428 acres